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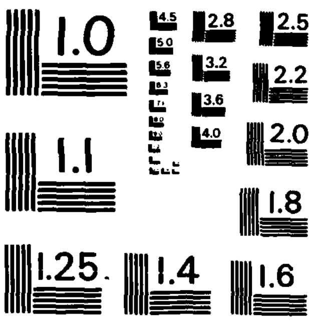

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AN ANALYSIS OF COMPUTER NETWORK FUNCTIONS FOR WRIGHT-PATTERSON AFB MEDICAL CENTER

THESIS

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Wright-Patterson Air Force Base, Ohio

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THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Systems Management

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AN ANALYSIS OF

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I. Introduction

Sky-rocketing medical costs and questionable patient care--how can they be improved? Reduced medical cost and improved patient care can both be achieved through the installation of a local area network. The process of collecting, recording, communicating, retrieving, and displaying patient information consumes an estimated twenty-four percent of all hospital costs (45:247). For the past five years, "the Department of Defense . . . alone has spent over 100 million dollars for its information systems in military hospitals" (45:248). The high cost of information processing is traceable to the complex and heterogenous nature of hospital operations.

Complexity in operations arises due to the different needs and characteristics of the patients. Such diversity requires the hospital to deal with each person in a unique way, from room assignment to billing. Room assignment, for instance, depends on a number of factors such as length of stay, type of ailment, and method of treatment. Different combinations of these factors require different solutions. Billing, however, poses a different type of problem. The hospital must now deal with not only the different methods of

reimbursement, but also the different sources such as insurance companies or government agencies. This kind of accounting problem, along with the previous scheduling problem, further complicates the operation of any information system.

Heterogeneity, on the other hand, arises from the host of special departments within the medical center. For instance, the information needs of the pharmacy, department of anesthesiology, intensive care unit, and laboratories are basically different (33:20). The difference is not only in type, but also in the amount of information that each functional area requires. Consequently, the complex and heterogenous nature of hospital operations often poses a coordination and integration problem to computer system managers.

Advancements in technology have recently enabled scientists and healthcare officials to address this major problem area: the need to integrate computer functions at the applications level (25:3; 45:250; 13:559). In a hospital, all computer systems share a subset of total information. This common information is duplicated in today's environment on each specific computer. The use of a network to link these computers opens up the potential for cost-effective distribution and coordinated sharing of information. This networking, often referred to as local area computer network (LAN), additionally offers the hospital information system the ability to perform functions such as electronic mail, teleconferencing, comprehensive data presentation, and many others not previously available.

In an effort to improve the flow and use of information, the medical center at Wright-Patterson AFB will install a LAN to link its computers. Although each computer already has an identified specific function, little knowledge exists as to what new computer functions are available once the LAN is installed. To help the hospital information system planners, this thesis will examine the functions that are available on LANs, and suggest which of these might be most appropriate for use at Wright-Patterson AFB Medical Center (WPMC).

Problem Statement

The recent decision to integrate different computers at Wright-Patterson AFB Medical Center into a local area network provides the hospital with additional computer functions previously unavailable. To help management select the appropriate functions to acquire and implement for this system, the goal of this thesis effort is to answer the following organizational question: Which computer network functions should management consider for implementation on the WPMC local area network?

Justification

The network designers, Mr. Raymond Girard and Lt. Lynn Kanwischer, have already taken the initial step of integrating the computers at WPMC. They have published a proposal request for the installation of cables and associated hardware for the physical linking of existing computers. Once

installed, this network will enable a user on computer X to run any program (such as word processing) on computer Y at no extra cost. This sharing is possible due to the communication media of the network.

This integration of computers will also expand the ability of the system to provide various clinics with a multitude of functions. To be cost-effective in acquiring any additional functions, however, administrators and physicians must reflect an interest and a willingness to utilize such capabilities. Indeed, some researchers have suggested that system designers tend to develop systems that are neither convenient for physicians nor responsive to their needs (47:542). Therefore, the goal of the integration process should be to tailor the information system to the needs of the hospital clinics.

Wright-Patterson AFB Medical Center will incur additional costs, however, if the computer system managers decide to implement new services on the installed system. A review of the network installation specifications and several interviews with the WPMC network designers revealed that no definite plan existed for the specific acquisition of network application packages such as electronic mail, broadcast service, and clinical decision-making aids (25:3-6; 19). To install the network and not implement functions such as these would mean only using a miniscule portion of the network's potential. However, the cost of acquiring all network functions would be too high and difficult to justify to budget

authorities. Consequently, determining which network applications are most cost effective and productive became a major area of concern to the computer system managers, Mr. Raymond Girard and Lt. Lynn Kanwischer.

Problem Background

Costs of hospital care and the increasing knowledge base upon which physicians must rely are both rapidly increasing. Current computer systems are still largely characterized by automation of manual procedures with few decision-making or knowledge-sharing features, and the use of these systems is peripheral to the practice of medicine. The development of networking and distributed systems provide accessibility to unlimited information resources. As mentioned above, new techniques of data storage, data collection and presentation, including color graphics, teleconferencing, and electronic mail will win approval in the medical field. New developments in natural every-day language text-processing and conversational query capabilities will permit rapid dissemination of new medical information in immediately useable forms. Computer power, especially shared aggregate power, will open up new possibilities in the traditional areas of financial, administrative, and clinical medical practice. Local and regional computer networks will permit sharing data between facilities and physicians, thereby reducing redundant lab testing, improving joint decision making, and coordinating treatment (21:16).

The problem of realizing the advantages of LAN's relate to two principal issues:

1. The general attitude toward computers; and
2. The attitude of administrators and physicians toward clinical applications of LAN.

The first issue reflects the problem of a lack of knowledge and over-optimism. Many healthcare professionals undoubtedly feel that the "computer is the true marvel of our century and that nothing of any significance will completely avoid its use " (17:425). The layman is often persuaded that nowhere is the influence more "marvelous" than in the field of clinical medicine. "The technical press and popular media, being naturally more inclined to report technical achievement than failure, make great play with each" new advance that science has to offer in medical computing (17:425). Hence many healthcare professionals, including network designers, are eager to install computers and associated devices. When asked what they will do with these systems, most hospital personnel cannot offer a specific function. One solution is to use the experience of other medical center users of LAN's as a guide.

The second issue relates to the professional's acceptance and use of computers. According to a survey involving 32 medical computer systems, about 50 percent had either been abandoned or temporarily halted over a five-year period. In only 19 percent of the cases did the authors report they were in routine use (17:425, 41:280). Additionally, one

researcher reports that "over-stated accomplishments from past computer research have led to some skepticism about future applications" (40:22). After reviewing articles containing questionable accomplishments, the physician, or medically oriented administrative professional, does not always believe the stated capabilities of computer networking. Another factor contributing to this lack of acceptance and understanding is that "less than two percent of the 1981 graduates of medical schools or professional health courses had elected courses in computer science" (1:202).

Order of Presentation

Chapter I has presented the problem and the justification for research. Chapter II discusses the relevant literature on medical LAN applications. Chapter III enumerates our research methodology and discusses the limitations on our analysis. Chapter IV will present the analysis, findings, and suggested applications for hospital LAN implementation. Finally, Chapter V will summarize the overall research effort, examine potential flaws in our approach, list conclusions and give recommendations for further research.

II. Computer Networks and the Hospital

Introduction

This chapter defines a selected number of computer terms, discusses local area networks, reviews expert opinions on medical computer network applications, and examines the background of the Wright-Patterson Medical Center (WPMC) computing efforts. The information contained in this chapter will provide a foundation for understanding the overall thesis problem area.

Automated Technology

The term "computer" means many things to many people. To the layman a computer is anything from a calculator to a billion dollar giant supercomputer. First, to lend a common background for discussion, we broadly define the different types of computers. Next, in a separate section, we treat the subject of networks in a similar vein.

Computers

Computers have generally been classified into three types: the microcomputer, minicomputer, and mainframe. These three types are active in most computer networks.

A microcomputer is perhaps best exemplified by the popular personal computer. A microcomputer has four primary characteristics:

1. Small size.

2. Internal processor and memory.

3. Ability to load, run, and store its own programs.

4. Low cost.

The small size means that a micro can fit onto a common desk. Some are only as big as a small portable TV; others take up an entire desk. All microcomputers have some type of central processing unit--the component that regulates the operation of everything within the micro. Most micro's can store from 1,000 to 256,000 pieces of information in their internal memory. Most functional micros also have either a cassette tape deck or small record-like disk drives for program storing. Micros generally cost less than 10,000 dollars.

The distinction between minicomputers and mainframes are less clearly defined. Generally speaking, a minicomputer has the following distinguishing features:

1. Ability to process relatively large and complex jobs.

2. Moderately high cost.

3. Medium size.

A minicomputer usually can support a number of users interactively. In other words, ten terminals may be wired to the minicomputer, and through a complex process, each one uses a portion of the minicomputer resources. Minis cost anywhere from 10,000 to approximately 100,000 dollars. Size varies, but generally a minicomputer occupies five to 20 square feet.

A mainframe computer is categorized as a "large collection of components, in separate cabinets, whose cost, complexity, and power are all high" (37:849). Computers grouped

as mainframes can cost from 100,000 to over several million dollars. One, two, or as many as several hundred terminal users may have interactive access to the central processor. Typically a mainframe occupies an entire room of several hundred square feet. Additionally, unlike most micros or minis, a mainframe requires an environmentally controlled room.

Technology is changing so rapidly that today's mini is yesterday's mainframe. Smaller and smaller components, new technology in manufacturing, and a host of other factors make a precise definition of these three key computer types virtually impossible. The important point is that in whatever size or form, these computers provide users with new tools to enhance productivity.

Computers in Medicine

More information demands are placed on medical professionals than ever before. No one can contest that,

> In today's complex society, hospitals are continuously challenged to provide medical care of high quality and volumes of information while simultaneously containing the cost of such services [13:559].

As information demands mushroomed, computers were introduced to handle the more routine tasks.

Accounting was one of the first areas in which computer applications were developed (45:247). Computer use has since grown into other hospital areas such as patient billing, room assignments, food services and menus, equipment inventory, staff payroll, and appointment scheduling to name a few.

Prevalent Models

Two basic models characterize computers in the typical hospital. The most common is the central mainframe which users throughout the hospital may access on an interactive basis. This mainframe runs all user programs and stores healthcare data in a number of different files. Though having obvious advantages of central control and ease of access, as medical specialization, technology, and information demands increased, the constraints of a single vendor's hardware / software system became apparent.

Technology played a key role in the development of today's hospital computer model by making it feasible for many vendors to develop lower cost minicomputers, each designed to fulfill a specific need within the numerous departments and clinics. As one researcher reported, "Hospitals desire and require customization which often conflicts with a vendor's need to maintain a uniform product among customers" (45:251). Others report, "The historical trend toward hardware customization will continue or the demands for software modifications will become prohibitively expensive" (48:23). Although the many aspects of customization lend obvious advantages to this modern proliferation of minis, there is a significant disadvantage in the fragmentation among multiple computers, each with its own file structure, file management, and criteria for information retention.

Little, if any, sharing exists among the fragmented

components of most administrative, financial, and clinical computing systems. At the WPMC, for instance, the patient's name, social security number, key demographic and financial information, activity status, and location are stored in at least eight different computers (18:2). The total amount of extensive storage space wasted due to redundancy is unknown. How much time is wasted looking up, calling for, or writing memos and letters to get information that exists on the computer system down the hall? What does it cost to have the same data stored on expensive computer hardware in a number of different locations? These questions point toward the beginning of the potential savings that professional articles discuss. An additional key point made by most authors in the networking literature is that clinicians and administrators need access to information available from all functional areas related to a given patient without undue difficulty, cost, or error.

Current Problems

Medical research literature has been quick to point out problems with current hospital computer systems. Each specialist has his own view on required computer functions. Dollar constraints add another dimension to the question of evaluating potential hospital computer systems. Different management views and the realities of budgets have led researchers to question whether the standards of care are uniform within hospitals throughout the nation--what could

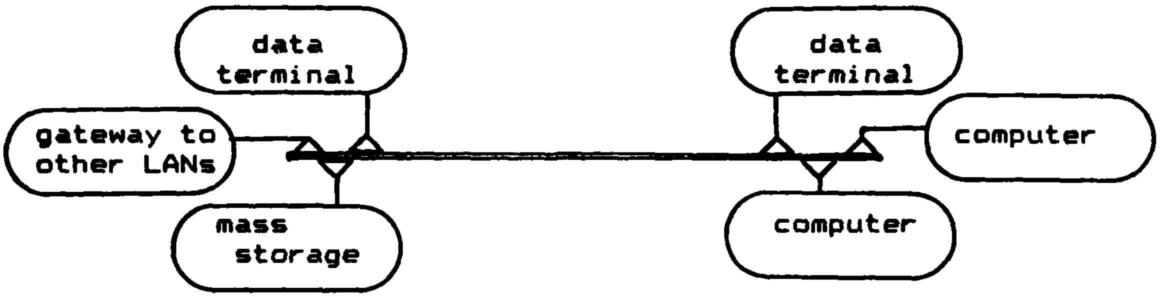

Figure 2.1 Typical Local Area Network

computers accomplish for the patient and administrator if they were widely available in every health care facility?

Networks

The potential for cost-effective distribution and coordinated sharing of information processing systems is substantially enhanced by the recent emergence of comparatively cheap, very reliable, high speed local area networks (23:343). Just as the term implies, a network is merely a means by which several computers can "talk" to each other. The concept has been compared to a television network where individual stations, some more independent than others, are linked together so a service (program) of one can be used by all (31:57). Figure 2.1 is an example of a type of network (2:47). Computers are finding their way into a multitude of functions from the accounting department to the laboratory. The network provides the capability for "full, direct connectivity so that the user can access multiple computers from a single terminal" (2:21). The need for and power of this

capability is analyzed in the application section of this chapter. The key goal is to provide fast access to shared information. Computer networks are grouped into three classes:

1. Communications network.

2. Resource sharing network.

3. Distributed computing network (16:11-13).

A communications network exists primarily to move data from one location to another. The data can take many forms from a simple one line message to a whole "packet" of information such as those contained in a computer-to-computer file transfer. Such networks are often characterized by the concentration of all user application programs (e.g., word processing) and data bases (e.g., patient admittance records) on one or two large mainframe systems in the network (16:11).

A resource sharing network exists primarily to permit sharing expensive computer resources among several computer systems. Shared resources not only consist of peripherals such as mass storage devices, but also can include logical entities, such as a centralized data base. Such networks are often characterized by the concentration of high-performance peripherals, extensive data bases, and large programs on one or two mainframe systems in the network (16:12).

Distributed computing networks coordinate the activities of several independent computing systems and exchange data between them. Distributed computing systems are usually characterized by multiple computers with application programs and data bases distributed throughout the network (16:13).

The term local area network, or LAN as used throughout this thesis, most closely corresponds to the distributed network. Local network development has primarily responded to the user's demand for more computer capability and flexibility. More and more users are installing minicomputers as the feasiblity of dedicated computing is realized. Yet, although the expense of these central processing units is decreasing, the "cost and complexity of high-performance peripherals such as impact printers and high-capacity disk drives remains relatively high" (22:81).

The LAN cable being installed at the WPMC will link six main computers and, eventually 11 other minis into a single resource sharing configuration. The advantages of networking are apparent when examining the available opportunities. Each area within the local network maintains its functional independence; yet each has complete freedom to gather research data from other users and to share their resources (e.g., disk storage, programs) during limited local system failures. A network-based distributed system can also give access to an entire range of commercial, military, and university-based computer resources (8:480).

Network Problems

Networks promise a wide range of previously unavailable opportunities. There are, however, a host of technical engineering problems associated with the actual installation and

interconnection of computers. A significant problem resides in the unfortunate fact that the WPMC, and indeed any large organization, uses computers from many different vendors. Each vendor uses a slightly different technique in the internal design of his brand of computers. This practice leaves the user with the problem of having his "orange" not being able to communicate with his "apple." This communication (or protocol) problem is just one of the major interconnection problems that have been only partially solved. The solution of this technical problem, however, is the realm of the engineer; therefore, hardware problems are not discussed in this thesis. The subject area concentrates on capabilities that will be available once technical problems are resolved and the network is installed.

The Solution - LAN

As stated in the network section of this chapter, recent advances in technology permit the efficient and cost-effective introduction of a common computer connecting medium, the LAN. Several hospitals in the United States have installed prototype LANs with reported positive results. Pioneers in this field have been the Johns Hopkins University and University of California at San Francisco hospitals (49:1-10). Users of these and other operational networks all favorably report using many capabilities that were not previously possible in the older mainframe or mini environment. Having access to the LAN, to transfer information at relatively high

TABLE I

Network Functions and Benefits

1. Bulk data transfer.	10. Fascimile tramission.
2. System fault tolerance.	11. Clinical decision-making
3. Graphics generation.	12. Teleconferencing.
4. Electronic mail.	13. Data Base Mgt Systems.
5. Access to national medical/ science network data bases.	14. Rapid-modular growth of hospital systems.
6. Revenue tracking.	15. Interactive query / resp.
7. Broadcast message routing.	16. Task mgt and coord.
8. Multicast message routing.	17. Computer-based education.
9. Sequential message routing.	

rates and to share the processing of a given task among different information processing resources almost always leads to an overall power and flexibility that is greater than the sum of the individual components (23:343). Key benefits only available or enhanced through access to a LAN include those in Table I (2:14-222; 34:2; 23:343; 30:1330-1338).

Application Analysis

The capabilities (or applications) for a powerful medium such as a LAN are limited only by imagination and technology. The above-mentioned uses are but a portion of the functions networks are or will be performing in hospital environments.

As is the case with any series of computer functions, some receive more treatment in the literature and are more popular than others. Four of the most popular, widely implemented, and most useful functions, according to health professional reports, are

1. Electronic mail,
2. Data base management systems,
3. Clinical decision making, and
4. Network access ability.

Each of these areas, along with professional opinion, will now be discussed in turn.

Electronic Mail

One of the first and most obvious applications of a comprehensive communication network is for message routing. Electronic mail has been defined as a computer message system which offers many of the "facilities of a conventional (non-electronic) mail or memo distribution system, but with vastly increased speed and convenience" (38:55). The effectiveness of any distribution system depends on how many users have convenient access to the medium. In the typical hospital, electronic mail cannot be implemented effectively because message transfer is usually limited to computer terminals within each clinic. The LAN, however, permits users in one clinic to communicate with users in a totally different computer system in another area of the hospital.

The nature of the electronic mail medium offers several

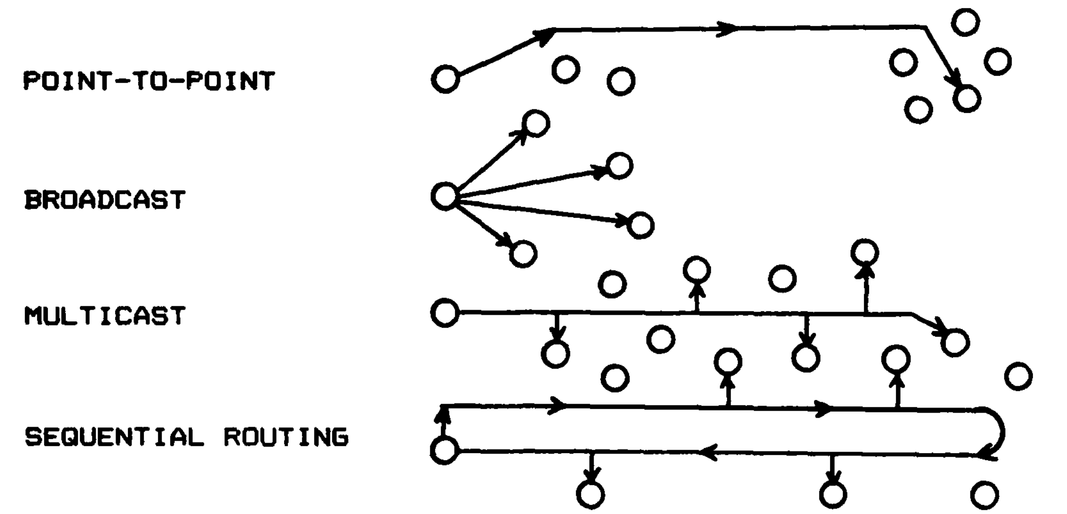

Figure 2.2 LAN Addressing Services

advantages to the user. First, unlike telephone conversations, one can proceed immediately to the point without having to first engage in small talk. As a side note, users have reported that they could write tersely and type imperfectly, "even to an older person in a superior position or to a person one did not know very well, and the receptionist took no offense" (30:1331). A second benefit is that electronic mail produces a preservable record. Messages can be sent to people even if they are not at their office; when they do arrive the messages are waiting. Finally, and perhaps most important to network utilization of electronic mail, is the availability of multiple addressing techniques. Oftentimes, users want to be selective in transmitting their memos. Figure 2.2 details the very powerful options available to message originators (2:92). The point-to-point,

broadcast, multicast, and virtual features available with electronic mail make it an extremely rapid and comprehensive means to contact different personnel. Also available is a status indicator with each mail item. In other words, a person can track the response to his message transmission by requiring an acknowledgement indicator be sent upon receipt and understanding of the original message. Through these addressing means, a person can also route a memo in-turn through the system. This feature alone can save considerable time in transmitting a memo from one person to the next who may be some distance away. The savings over hand-carrying messages or using conventional mail are limitless.

The electronic mail system can also incorporate text processing features to aid in the generation of the messages. User instruction systems, means for indexing, filing, summarizing and retrieving mail can also be incorporated to fully utilize the power of the computer network.

Concerns of Electronic Mail Use

Authenticity is one of the most frequently raised concerns for users of a computer-based message system. Authenticity, or message security, implies two concerns: that the message text has not changed since it left the sender, and that the identity of the sender is correctly represented in the text header or in the signature attached to the message (11:55). Similar factors involve ensuring the system makes messages available to no one but the intended recipients and

that a message reportedly originated by user X really came from user X (38:61).

There is always the possibility that one or more of the recipients in a routing index will need to alter the memo, or that external agents will interfere with normal communication. Many existing LAN models incorporate special software features to ensure spurious message injection, modification, or fake node rerouting do not occur. Operating networks incorporating these features include those offered by IBM, Digital Equipment Corporation, and the governments' Advanced Research Projects Agency network (24:8). Ultimately though, "the security of a communications system lies in its ability to meet specific operating requirements despite the actions of a knowledgeable and determined attacker" (12:40).

<u>Data Base Management Systems</u>

As one researcher reports, "major breakthroughs [in hospital care] will occur in the next 10 years as the result of the availability of new, low cost, data base management systems" (43:14). The advancements will be possible through the increased speed, accuracy, and completeness by which medical data may be entered, stored, sorted, and retrieved. Further enhancement is achieved through the existence of a common network of computers, all tied into a single data base. The power of having one all-inclusive information repository is that physicians will be able to instantly access patient data from every location within reach of the LAN. Previously,

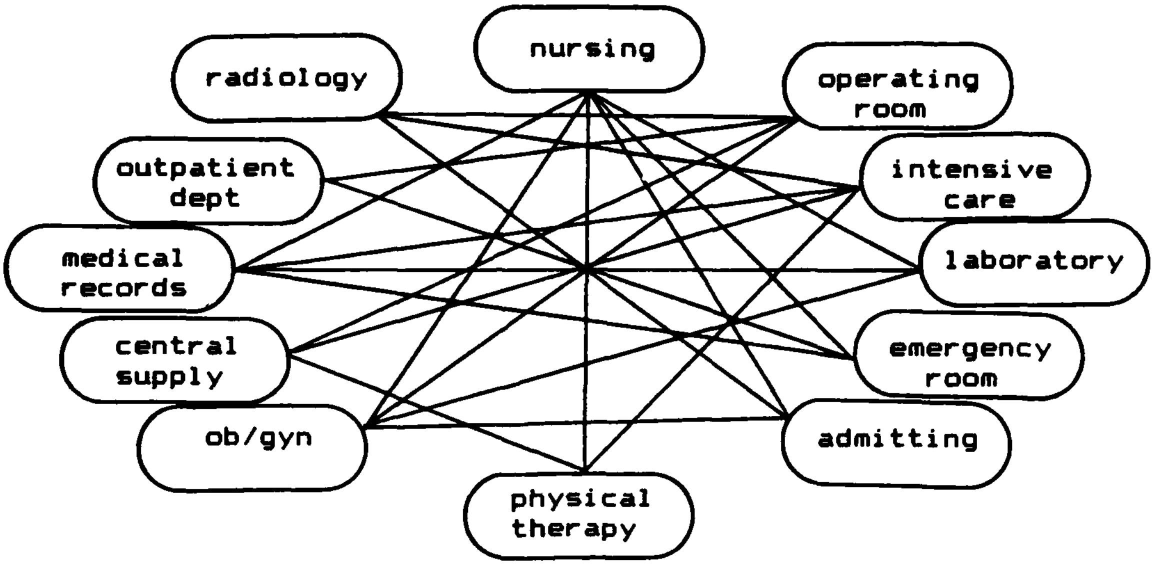

Figure 2.3 Average Information Flow

physicians might have had to query several different computers to find the required information.

A common concern of today's medical centers is that no compatibility and consistency exist between information systems administration and a hospital's general administrative philosophy. Figure 2.3 illustrates the information flow in an average hospital (46:72). The figure shows a situation characterized by multiple information repositories--redundancy and chaos are the norm. Figure 2.4 illustrates the medical facility that utilizes a central data base (46:73). The single hospital data base serves three principal functions: elimination of inconsistent and uncorrelatable data, establishment of a unifying structure for all programs to follow in data storage and retrieval, and rapid access to all

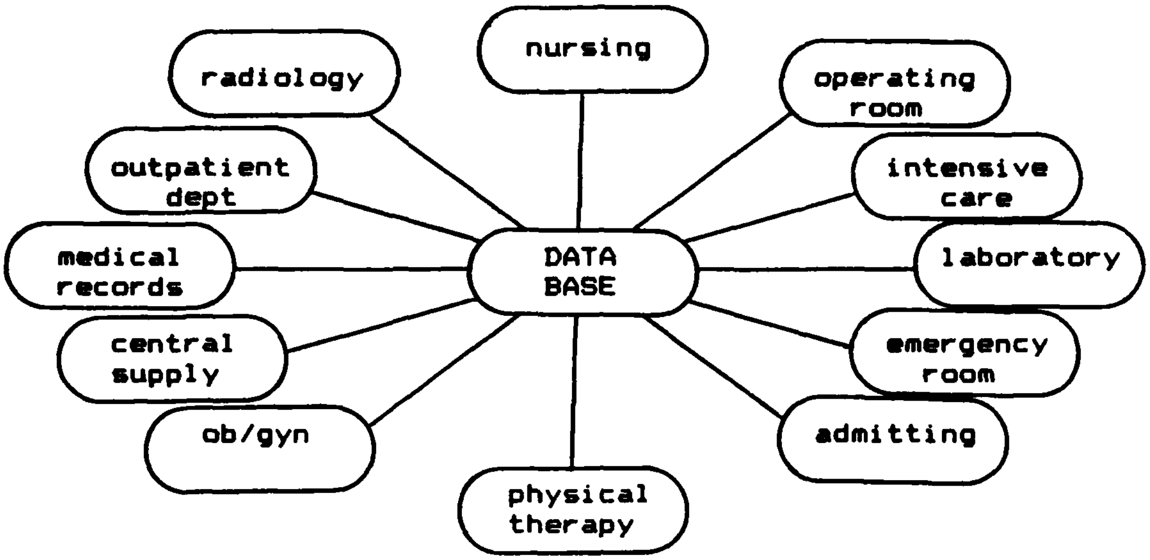

Figure 2.4 Modern Information Flow

available data in a unified rather than unorganized or fragmented structure.

Instantaneous updates and status actions are further benefits of a central data base accessed by a convenient LAN. Consider the example of patient records. Under today's frequently fragmented situation (Figure 2.3), patient records are never complete until checkout. Theoretically, the patient arrives at the hospital and the receptionist fills out an entry form. This form is sent to the records section where, several hours later, the record is updated. Meanwhile, the patient sees a doctor who may or may not have seen the admission form and primary record. The laboratory may have to perform blood tests. Again, time is wasted while the results catch up to the record.

In the LAN arena with a central data base, the process is more efficient. Receptionists and lab technicians electronically enter data into the primary patient record as information is generated. A doctor can now request the current status on all or part of the patient record with the latest information at any time and any place, in his office or during his rounds through the hospital. Everyone with a need to know then has access to a patient's total status, without having to wonder if there are some lab results or other data that have not yet caught up to the records (3:2047).

Another unique advantage of the central data base management system is the provision for sophisticated querying, such as trend analysis. For instance, a physician can access any subset of several patients records to see if an adverse trend exists. In one hospital in Austria, a trend indicating abnormally high waits for bypass surgery was only discovered after this type of complex data base query was performed (5:579).

Data Base Problems

As in every technological advance, some concerns exist. The perceived barriers to the use of centralized data base management systems include: cost, inconvenient access, lack of available expert consultation for help in query formats, and sometimes, the simple communication gulf between medical investigators and computer scientists (26:482).

Cost is one area where there are both positive and negative tradeoffs. In a positive sense, the use of a central data base eliminates the use of a wide variety of incompatible, redundant, and perhaps underutilized individual data storage devices. Economies in scale and in access speed can be achieved through the use of a single storage device. On the other hand, complex programs required to implement a useful data base access medium are expensive and may require additional technical personnel to serve as data base administrators to ensure compliance with standards. To determine the usefulness of the system, computer managers must be able to properly define and weigh these costs and benefits.

The resolution of technical barriers and implementation of the LAN essentially obviates the majority of access barriers to the data base. In a LAN environment, anyone with a terminal can access the central data bank -- previously, they could only access the computer within their individual clinic.

Again technology and sophistication in recent programming efforts have played a major role in making it easier for a layman to format an effective query for data. Professionals concerned with specific medical information should be able to access and analyze the data directly without having to go through an intermediary such as a computer programmer. In an effort to provide rapid and easy data base access to physicians with little computer experience, medical experts at Vanderbilt University have developed a new access system.

This system incorporates a natural language interpreter so the doctor can type in english-like sentences in question format to the computer. This effort, though still somewhat limited, is making easy access a reality (51:41). Efforts are also underway at Digital Equipment Corporation and Honeywell to improve the inter-relationships of network data bases so that data retrieval requests produce more efficient and effective results (28:82; 5:576).

Communication problems between engineering-oriented computer scientists, health-care officials, and physicians will always exist to some degree. Some researchers, however, feel that the increasing proliferation of computers into our daily lives will lead to better awareness, comprehension, and acceptance of computer terminology.

Technology has resolved many of the major impediments to using data bases effectively. The ultimate realization of increased productivity can only be achieved if healthcare professionals are willing to learn and use the services offered by an easily accessible data base management system.

Computer in Clinical Decision Making

Computer-based medical decision making is an area that has received much attention in the past few years. Declining hardware prices, successful implementation of sophisticated data base storage techniques, and faster, more convenient access to data have made possible the introduction of systems that aid the doctor or nurse in making decisions.

No individual can possibly assimilate all the medical knowledge that is being published each year. The trend toward increasing specialization in medical schools throughout the last ten to 15 years was an attempt to deal with the mountains of knowledge in each medical specialty. Technology and medical research have increased the amount of available information faster than specialists could absorb the new developments. One study concludes that most physicians complete a patient examination and render a diagnosis using only about 70 percent of the potentially useful information (39:27). Another researcher amplifies the lack of knowledge by stating that the "failure to use [computers] will lead to erratic and probabilistic thinking that can do harm to the highly improbable, unique individual" (50:27).

Over 58 empirically tested computer-aided medical diagnostic systems have been in use throughout the hospitals across the United States. Each of these was specifically developed to aid the physicians' memory. The designer of one of these systems explained their benefit by pointing out that

> The gap between the information which exists for diagnosis and that accessible from memory is difficult to close even for a highly trained general practitioner with substantial daily exposure to many disorders. The computer based systems for diagnosis are created to help the physician bridge the gap [41:268].

In terms of providing access to and development of the data required to insure decision making packages are effective, the importance of the LAN cannot be overemphasized. Researchers list the LAN enhanced information capability as

being one of the essential elements in the successful implementation of the reported 58 current systems (41:274). Of primary importance to those designing LAN systems for clinical decision making is the widely reported fact that current decision package designers' goals are " . . . to improve the information available to physicians in regard to disease identification" (47:543).

The LAN is a major asset to the use of any clinical diagnostic system. The LAN provides universal access to 100 percent of the current information on any aspect of a patient. The physician no longer has to be within his own clinic to access the data on his department's computer. With a LAN, the doctor theoretically has access to data anywhere in the hospital--operating room, pharmacy, laboratory, and office. The doctor not only can feed data into the LAN seeking an answer to a particular question, but he can also be prompted, receive treatment or dosage suggestions, and obtain statistical probabilities for a particular disease (27:18).

Massachusetts General hospital first implemented one of the more popular systems called MUMPS (Massachusetts Utility Multi Programming System). This system's central component is the hospital-wide Information and Retrieval System, which for all practical purposes is a LAN. Figure 2.5 illustrates a simplified version of their network diagnostic system configuration (7:41). In a study of MUMPS effectiveness, researchers reported 91 percent accuracy in diagnoses of

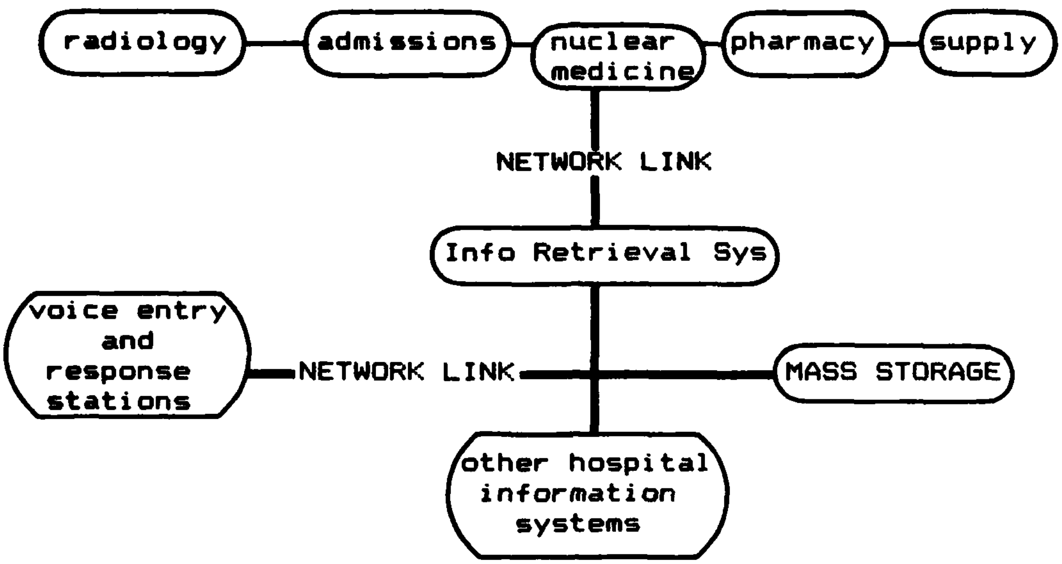

Figure 2.5 Massachusetts Network

sample cases using the computer system, and 84 percent accuracy of diagnoses using physicians opinions and estimates (41:274).

Doctors at Latter Day Saints hospital in Salt Lake City reported significant benefits in using their diagnostic system. In spite of the relatively high cost of collecting the data for computer analysis, the system proved so successful in reducing unnecessary surgery that insurance companies have underwritten the cost of further system enhancement (6:30).

Significant technical, legal, and human factors problems exist in the implementation of clinical diagnostic systems. Several of these problems have been resolved in the existing systems. However, the aspect of human use or acceptance may never be resolved to everyone's satisfaction.

The two major sociological problems are a lack of large, statistically significant data bases to insure validated diagnostic accuracy, and the difficulty in quantifying what many physicians feel is an art--diagnosing a disease. Problems with data base information comprehensiveness and access have been partially solved as discussed in the previous section. As an aid in quantifying the decisions involved in diagnosing a disease, several approaches have been taken. These include flow charts, Bayesian statistical analysis, sequential questioning methods, and decision tree approaches (36:20; 41:272). These approaches have led to results which come close to or even exceed the average ability of physicians. More testing is undoubtedly in order before the clinical decision package emerges as a clear winner.

Legal problems are a major concern of many people when they think about implementing the clinical decision making packages (29:607). Such questions as the following are but a few of the ones raised during interviews:

1. What is the legal effect if the doctor follows the diagnosic conclusion of the computer that later turns out to be wrong?
2. What is the legal implication if the doctor fails to use the computer for assistance; the doctors individual conclusion turns out to be wrong; and the suggested computer solution is shown to be correct?

These questions, and other similar ones, will take time

and many court battles before they are resolved. However, the number of systems already implemented shows that the legal problems are not an insurmountable obstacle.

Human factors impediments to successfully implementing decision making systems are of concern. Specifically, the most important aspect of the human problem is the attitude toward the use of computers for anything more than calculator-like functions. This area affects not only decision making packages, but also the entire realm of computers. A separate section follows on human aspects of automation in the hospital.

Computers - Human Attitudes

If health care personnel fail to use the computers, then the benefits of local area network will never be fully realized. Computers must be "considered in light of the appropriateness of their fit with human users in the actual, prospective work environment " (14:254). This consideration is crucial or no benefits will be gained. Several researchers argue that lack of contact with the end users of a proposed system is a common problem--often, the developed systems are neither convenient nor responsive to needs (47:542).

Information management is key to medical practice. Today's doctor must store and process individual patient historical data, diagnostic and therapeutic rules, disease trends, and published knowledge in healthcare (29:607). Physicians face two problems with the current information

explosion: first, no one can afford to spend the necessary time to assimilate all the published patient data without decreasing the standards and quality of patient care; and second, a physician might feel a certain loss of prestige if he is to rely on the computer extensively for assistance. The reason for this loss of prestige is that many doctors feel their unique skills in observation, knowledge, and experience are sacrosanct (29:608; 47:542). This particular feeling is the major finding of a study on physicians attitudes toward computers. The study reported that applications presented as aids to clinical decision-making were "more readily accepted than those that involved the automation of clinical activities traditionally performed by physicians themselves" (47:553). The researchers also noted that there was an important and clear distinction for decision-making packages to be presented as aids rather than replacements (17:426).

Many physicians and other hospital personnel posses a common quality--resistance to change. This resistance corresponds with a long history of tradition--"We have always done things this way; why change now?" Properly explained benefits might help to solve this natural aversion to something different. Ideally, a computer system can and should be designed to minimize changes in established hospital procedures. Designers should not, however, be so reluctant to use new technology that they fail to use computers at all (4:14).

Authors also agree that increased emphasis on computers

in medical school can lead to a greater acceptance of new automated possibilities. The nature of the medical school environment must be modified to reduce the reliance on interns, residents, and students for patient data rather than computers (29:608). Much of a physician's training deals with how to make optimal, informed decisions in all clinical areas. A modern benefit of the current computer explosion in home systems is that people in medical school will have more exposure to business and clinical applications (44:11). A careful and non-technical explanation of potential benefits of LANs can ensure those doctors not familiar with computers a better understanding of the new aids available to them.

Local computer networks are particularly susceptible to user rejection because of the oftentimes complex instructions required to use network services (9:275). The main reasons for rejection are a perceived lack of need for every network feature and a failure to indicate the willingness to learn and use potentially useful services if they are available. One author's suggested solution to the problem of acceptance is to ensure LANs are simple, understandable, guarding, and trustworthy (10:33). Although doctors can be repelled by the notions that quality of life, pain, risk, and disease likelihood can be quantified, the proper explanation of what network functions can do to aid them in the clinic can go a long way toward making the implementation of those functions successful (47:543-544). Additionally, once a physician understands a particular benefit and continues using it with

favorable results, his peer influence can go a long way toward increasing the rate at which new automated medical technology is introduced (1:200).

The human aspect is vital in the design of any system. Considering the users' acceptance of a new application before purchasing the necessary hardware and software is crucial to ensure the system's success.

Network Access Capability

The installation of a LAN provides the technological medium for access to a host of other distant computer systems. Other hospitals that have computer networks can be accessed by a network-to-network interface called a gateway.

Access to another network can provide users at WPMC, for instance, with data management or processing services that are not available in the local network. Any individual terminal on the network could not only access any computer on the LAN, but also any computer on another network (42:19). Rapid access to medical information in different hospitals would permit data entry, updating, and trend querying to occur on a truly comprehensive scale. Physicians will then be able to statistically validate diagnoses on the entire population rather than error prone sample data. True sharing of test results, improved decisions through rapid consultation, and the coordination of new techniques are all enhanced by the interconnection of gateways (21:16; 43:14).

A critical feature of the capability to access other

hospital networks is the idea of redundancy. No doctor could afford to be suddenly without his computer due to a malfunction. If the LAN provides access to other hospital networks then, by storing backup copies of critical information at alternate sites, he can simply use a similar computer in another location. The power for reaching additional resources is a key consideration in ensuring the continuous operation of vital computer fuctions.

Wright Patterson Medical Center

This thesis deals with the issues of application usefulness at Wright-Patterson's medical center (WPMC). As a prelude to the remainder of this paper, we provide the reader with a brief synopsis of the current computer situation at the WPMC.

Background. The chief of medical computing is Mr. Raymond Girard. Working with him on the design of the LAN project is Lt. Lynn Kanwischer.

WPMC is a large regional hospital supporting a ten state area. The medical center is currently undergoing a five year expansion to double its size to 630,000 square feet. In concert with this expansion, Mr. Girard and Lt. Kanwischer have spearheaded a drive to install a LAN to modernize administrative functions and to improve patient care.

Eleven minicomputer systems are currently in use at Wright-Patterson AFB Medical Center. These systems include

1. Tri-Service Laboratory Information System, DG 350.

2. Tri-Service Patient Administrative Data Base, DG 350

3. Computer Cardiology System, DEC PDP 11/34.

4. Wang Office Information System, OIS 140.

5. Wang Virtual Storage System, VS 190.

6. Uniform Chart of Accounts System, Datapoint ARC.

7. Advanced Cardiac Catheterization System, Honeywell.

8. Hewlett-Packard Graphics System, HP 2647F.

9. Computerized Arrhythmia Monitoring System, HP 78930A.

10. Wordstream Word Processing System, WS2200.

11. Nuclear Medicine ADAC, Clinical Data Systems, CAM2 (25:20).

These systems perform specific functions within different clinics, and none of the systems have access to potentially valuable information on another. The immediate goal of the network is to integrate the first six computers into a local area network (LAN).

LAN Planning. All planning to date has consisted of preparing the specifications for the LAN cable to connect the various computers. Extensive efforts have been made to plan for cable installation around the current construction so that, at the end of the five year expansion, the hospital will have a comprehensive connecting cable throughout the facility.

Little planning exists as to what use might be made of the LAN once it is connected. No specific programs to pro-

vide electronic mail, data base querying, decision making, or access to other networks are currently envisioned in the next five years. During interviews, the LAN designers reported a lack of knowledge on what hospital personnel are interested in using or acquiring.

Chapter Summary

A new era is dawning at the Wright-Patterson Medical Center. Radically new technology provides the capability to exercise functions that could only be dreamt about several years ago.

Network designers are aware of what functions LANs could perform. Other hospital personnel, however, are not as aware of the possibilities. Literature provides many illustrations of LAN benefits that can be proposed to physicians and other hospital personnel. A number of these applications are operational in hospitals around the United States.

A common factor in all articles of LAN applications was the need to carefully introduce the computer to the user. A survey of what people want to see implemented, along with careful explanations of benefits is widely reported as being a crucial step in the introduction of any computer system.

III. Methodology

Introduction

This chapter outlines the approach used in solving the research problem stated earlier in chapter One: to determine which computer network functions management should consider implementing at Wright-Patterson AFB Medical Center (WPMC). The chapter begins with an overview of the research design, specifically the research and investigative questions that guided the overall thesis effort. Next, this chapter discusses the general research methods, which consist of five main areas: review of literature, interviews with WPMC computer system managers, development of questionnaire, sampling plan, and analysis of results. Finally, this chapter summarizes the steps necessary in completing this research project.

Research Design Overview

As suggested by C. W. Emory in Business Research Methods, the initial approach to solving the stated research problem began with the development of questions that would guide the research (15:64-66). These "research questions" were then expanded into more specific "investigative questions" that provided the general framework for research design. The overall objective of these questions was to answer the following "management question": Which computer network functions should management consider implementing at

Wright-Patterson AFB Medical Center?

Research Questions

The following research questions were developed to guide the research:

1. What computer network functions will be available?
2. What is the perception of different clinics toward the usefulness of these network functions?

Investigative Questions

To solve the above research questions, the following specific investigative questions had to be answered:

1. What functions are available strictly to computer networks?
2. Which of these functions are relevant to clinical operations at WPMC?
3. How beneficial is each function to different clinics or departments?
4. How will each function affect the way medical personnel perform their jobs?

Research Methods

The first two investigative questions were answered by a review of literature dealing with medical applications of computer networks and interviews with Wright-Patterson AFB Medical Center computer system managers, Mr. Girard and Lt. Kanwischer. The result was a list of four functions that had been successfully implemented at other hospitals: electronic

mail, data base management system, clinical decision-making, and network access capability. The benefits, along with associated problems, of each function were fully discussed in Chapter II.

The next two investigative questions, on the other hand, required administering questionnaires to different clinics, and analyzing the results statistically to determine the perceived usefulness of each of the four listed functions. The overall research effort followed these particular steps:

1. Compiling a list of computer network functions from literature.
2. Interviewing computer system managers to determine completeness of this list, and to restrict this list to relevant functions.
3. Constructing a questionnaire based on background information and those relevant functions.
4. Determining the sample of medical personnel to administer the questionnaire.
5. Analyzing the results.

Literature Search

The initial step of the research effort was to review appropriate literature to compile a list of computer network functions that were applicable to hospital operations. The search process was divided into three phases: screening, collecting, and analyzing. The initial phase was to screen periodical indexes and abstracts, including a Defense Tech-

nical Information Center (DTIC) search, for articles pertaining to "medical center computer network applications." The next phase was to collect these articles. The sources were the Air Force Institute of Technology (AFIT) libraries, the Air Force Wright Aeronautical Laboratories (AFWAL) Technical Library, the medical libraries at Wright State University, Fort Carson Army Hospital, and Wright-Patterson AFB Medical Center, and the U. S. Government Printing Office.

The third and final phase of the literature search, however, was the most extensive of the three. The purpose of this phase was to analyze the collected articles for two basic reasons: first, to gather background materials for the research problem; then, after interviews with WPMC computer system managers, to obtain further details on the four network functions selected for the questionnaire. The background materials included a list of possible network applications, a general attitude of medical personnel toward computers, and finally, a review of present WPMC computers and their future capabilities. The results of this literature search were background information contained in the first two chapters and a list of functions available strictly to computer networks.

Interviews

The interviews were conducted with Mr. Raymond Girard and Lt. Lynn Kanwischer, who are the driving force behind the integration of Wright-Patterson AFB computer systems. The

purpose of these meetings was three-fold: first, to determine present and future capabilities of WPMC computers; second, to reduce the literature search list of network applications to relevant functions; and to identify departments at WPMC to administer the questionnaire. The information concerning WPMC computer systems capabilities formed the background materials for Chapter II.

The computer system managers were presented with a list of functions compiled during the literature search (see Table I). The completeness of this list was discussed; however, the final result of the interviews was a reduced list of four functions considered appropriate for WPMC operations. Due to the limited time allowed for data collection, the surveying population was also reduced to eight departments that Mr. Girard and Lt. Kanwischer identified as being potentially affected most by the implementation of those functions. These eight departments would make up the sampling population, while the four computer functions formed the basis for questionnaire development.

Questionnaire

The purpose of the questionnaire was to acquire data concerning medical personnel's perception of the usefulness of selected functions. Basically, the administered survey consisted of two parts: background information and main body (refer to Appendix A). The background section contained questions dealing mainly with a respondent's current job,

computer training, computer expertise, ownership of home computer, and satisfaction level with current WPMC computer capabilities. The answers to these questions would be used to analyze the effect of the respondent's background on his responses to questions in the main body of the questionnaire.

The main body, on the other hand, was further divided into four sub-areas, each dealing with one of the four selected functions. Each sub-area contained three related questions that were used to measure the following perceptions: beneficial level to department or clinic, anticipated amount of use, and effect on the job. The responses to these questions would provide an indication of a respondent's general perception of a computer function's utility.

Sampling Population

The eight departments identified by Mr. Girard and Lt. Kanwischer as the sampling population were Pediatrics, Family Health, Internal Medicine, Nursing, Pharmacy, Surgery, Mental Health, and Dental Services. The total number of personnel assigned to these departments was roughly 800, or about two thirds of the Medical Center population. The make-up of this sampling population was 24% physicians and managers (also referred to as professional staff), 43% nurses, with the remaining 33% going to technicians, clerks, and others. In contrast, the percentages of the entire Medical Center were 25, 30, and 45, respectively.

The number of questionnaires assigned to each department

TABLE II

Proposed Sampling Population

Depart-ment	Weight factor	Pro-Stf ratio	Non-Pro ratio	Surveys #	Pro-Stf #	Non-Pro #
Pediatric	5	.59	.41	10	6	4
Fam Health	5	.52	.48	10	5	5
Medicine	15	.45	.55	30	14	16
Nursing	30	.01	.99	59	1	58
Pharmacy	4	.15	.85	8	1	7
Surgery	16	.37	.63	32	12	20
Mental Hth	12	.57	.43	23	13	10
Dental	13	.28	.72	26	7	19
	100			198	59	139

was based on a weighting factor which reflected the personnel ratio of each clinic to the sampling population. The nursing Department, however, was assigned less weight than required in order to reduce this ratio to 30% which was a closer approximation of the actual percentage of nurses at WPMC. The excess weight was distributed evenly to the remaining departments, as appears in the first column of Table II.

Within each department, the assigned number of questionnaires was further divided into two groups based on the percentages of professional and non-professional staff, as indicated by columns two and three of Table II. The professional staff included managers, physicians, pharmacists, optometrists, and related professions. Columns four, five, and six reflected the number of questionnaires assigned to each department, to professional staff, and to non-professional staff, respectively. With the exception of the Nursing Department, each of these departments represented

roughly one-third of the clinic's population. The resulting percentage of professionals in the sampling population was 30% as compared to the actual figure of 25%.

Fourteen questionnaires were distributed to the command section of WPMC to further stress the importance of professional staff perceptions. This addition is particularly appropriate since these positions would are affected most, in terms of information flows, by the implementation of network functions. As a result, the total number of questionnaires distributed was 212 and the percentage of professional staff increased to 35%.

Data Analysis

The collected data was analyzed using the FREQUENCIES and T-TEST subroutines of the Statistical Package for the Social Sciences (SPSS). Initially, the FREQUENCIES subroutine was used to describe the make-up of the surveyed sample and to determine the overall responses to the usefulness questions relating to the four computer functions. The T-TEST subroutine was then used to check for significant differences in responses, with respect to background information such as current job, computer training, computer expertise, ownership of home computer, and satisfaction level with current WPMC computer capabilities. The results of this analysis step are discussed in depth in Chapter IV.

Chapter Summary

This chapter outlined the steps necessary in completing

this research project. The initial steps were to conduct a review of literature and interviews of computer system managers to compile a list of relevant functions used in preparing the questionnaire. Next, due to the time constraint, the sampling population was determined by selecting only eight departments that are representative of Medical Center computer users. Questionnaires were administered to these departments, and the resulting data analyzed.

IV. Findings and Analysis

Introduction

This chapter summarizes the responses to the survey that was administered to eight selected departments at Wright-Patterson AFB Medical Center (WPMC). The chapter is divided into three major sections: presentation of findings, discussion of results, and summary of analysis. Initially, the findings are discussed by first describing the make-up of the sampling population, then listing the frequencies of responses to both background and utility questions (Appendix C). Next, a test is performed to check the validity of the collected data, and the results are then discussed along with the necessary assumptions. Finally, this chapter summarizes the analysis of results by highlighting significant responses to the administered questionnaire.

Findings

From the original 198 questionnaires that were distributed to selected departments, 159 were returned for a response rate of 80.3 percent. Individual response rates for the eight departments are shown in Table III. Fourteen questionnaires were also distributed and collected from the command section at WPMC. The resulting number of collected questionnaires becomes 173 (out of 212 that were distributed) for an overall response rate for the Medical Center of 81.6 percent.

TABLE III

Departmental Response Rates (percent)

Pediatrics	70	Pharmacy	100
Family Health	70	Surgery	75
Medicine	100	Mental Health	70
Nursing	73	Dental Service	92

Sampling Population

Table IV describes the actual make-up of the sampling population based on returned questionnaires. The total number of surveys collected from each department is listed in column four of this table and the percentages that these numbers represent appear in column one titled "Weight." Columns five and six, on the other hand, indicate the numbers of surveys administered to professional staff (mainly managers, physicians, and related professions) and non-professional staff. The ratios of these two categories to the number of surveys from each department (column four) are listed in columns two and three, respectively. The resulting percentage of all surveys from professional staff to the total number of surveys from every department (159) is 35.8, as compared to the proposed 29.8 percent; however, when the fourteen questionnaires from the command section are also included in this computation, the actual percentage for professional staff increases to 37.6, while the proposed number was 36.9 percent.

TABLE IV

Actual Sampling Population

Depart- ment	Weight factor	Pro-stf ratio	Non-Pro ratio	Survey #	Pro-stf #	Non-Pro #
Pediatric	4.4	.71	.29	7	5	2
Fam Hlth	4.4	.43	.57	7	3	4
Medicine	18.9	.47	.53	30	14	16
Nursing	27.0	.12	.88	43	5	38
Pharmacy	5.0	.25	.75	8	2	6
Surgery	15.1	.46	.54	24	11	13
Mental	15.1	.44	.56	16	7	9
Dental	10.1	.42	.58	24	10	14
	100.0			159	57	102

Initially, these returned questionnaires were statistically analyzed using the FREQUENCIES subroutine of the Statistical Package for the Social Sciences (SPSS) program, version 8.3 (NOS), dated 4 May 1982 (see Appendix B). The results of this computer run were frequency distribution tables for the various responses to the survey questions, along with other descriptive statistics such as mean, mode, median, variance, kurtosis, and others (35:182). The desired statistics, however, were only the frequencies at which responses occurred. A summary of this computer run, with each number representing a percentage of the total 173 respondents is included in Appendix C.

Discussion

Each of the numbers in Appendix C represents a percentage of the total 173 medical personnel who selected the indicated response. Not included in this summary were

omitted questions, which were considered missing values for computational purposes, and answers such as "Not Applicable" that made up the remaining percentages to every question. The validity of these responses, especially to the utility questions, was then checked using another SPSS subprogram T-TEST to compare the means of different independent samples (Appendix D).

Pooled T-Test

The independent samples type of t-test was appropriate since the objective of this computer run was to compare the means of two independent groups (based on background information) using the responses to two of three utility questions under each function as variables. Only two questions per function were used because this test required interval data as variables, and only the first and third questions under each function qualified. The ranges of responses had to be converted into Likert Scale data by considering "Don't Know" and "Not Applicable" responses as missing values, thus reducing each of the two questions to five choices. Subprogram T-TEST was then used to compute Student's T and probability levels for testing significant differences between groups' means (35:267).

Five background questions were then selected, and the responses recoded to reflect different groups within the sampling population. These questions were concerning current job (Q-2), computer training (Q-4), computer expertise (Q-5),

TABLE V

Group Comparisons for T-TEST

Questions	Group 1	Group 2
Q-2	Professional staff	Non-professional staff
Q-4	No computer training	Some or several classes
Q-5	Novice or beginner	Intermediate or advan.
Q-6	Own a home computer	No home computer
Q-8	Satis with capability	Not satisfied

ownership of a home computer (Q-6), and satisfaction level with current computer capabilities at WPMC (Q-8). The groupings were as shown in Table V. The null hypothesis for this test was that the means of groups one and two were equal. In other words, the objective was to determine whether the differences in mean responses between the two groups, with respect to the two specified utility questions, were significant.

Results

Initially the groups of professional and non-professional staff (Q-2) were tested against the eight utility questions (Q-9, Q-11, Q-12, Q-14, Q-15, Q-17, Q-18, Q-20). This same procedure was repeated with the remaining groups for a total of 40 tests. Except in two cases, the results of these tests failed to reject the established null hypothesis with a confidence level of 95 percent.

In the first case, the mean responses of professional (4.234) and non-professional staff (3.862) to question 11 (Effect of Electronic Mail on Job) were possibly different.

In relation to question 12 (benefit from DBMS), the same results occurred when the mean response of the group without any computer training (4.767) was compared to that of the group with at least some computer courses (4.441). The "two-tailed probability" for these two tests were 0.017 and 0.009, respectively; however, in both cases, the mean differences not only appeared to have negligible effect on the overall mean responses, but also seemed insufficient to invalidate the entire data collection process. Consequently, the results of these forty t-tests indicated that changing the sampling population's make-up with respect to the five background questions would only change the overall responses slightly.

Assumptions

In performing each pooled t-test, some assumptions had to be made concerning the grouping within the sampling population. The accuracy of these assumptions, consequently, determined the validity of the tests. The four necessary assumptions were as follows:

1. Independent samples were selected at random.
2. Unknown population variances were assumed equal.
3. Collected data had interval level of measurement.
4. Underlying sample distributions were normal (32:368).

Among these, the weakest assumption was the last one dealing with the normalcy of distributions. The tests, however, would be insensitive to slight violations of this assumption

had the sample sizes been sufficiently larger (usually greater than 30) (32:307). Consequently, all samples with sizes less than 30 were tested for normalcy of distribution using the non-parametric Kolmogorov-Smirnov test.

The SPSS subprogram NPAR TESTS (K-S) was used for this purpose, and as suspected, not all sample distributions were normal. Eleven out of 21 samples had some distributions other than normal, and this result could have a possible impact upon the validity of the previous t-tests. Although this impact could be significantly lessened if the overall sampling population were larger in size, this finding remained a weakness in the analysis of collected data.

Summary

The data collected from the eight departments at WPMC were statistically analyzed using different SPSS subprograms. The results of these tests discussed, and the findings presented with respect to background and utility questions. Responses to background questions provided information on the sampling population's make-up, while responses to utility questions reflected the respondents' perceptions of computer functions' usefulness.

Table VI further summarizes the respondents' perceptions in terms of favorable and unfavorable responses to these utility questions. With respect to each computer network function, a favorable response indicates a respondent's perceptions that this function will be beneficial to his depart-

TABLE VI

Favorable Versus Unfavorable Responses

Utility Question	Elec Mail Favor	Elec Mail Unfav	DBMS Favor	DBMS Unfav	Diag Sys Fav	Diag Sys Unfav	Net Access Fav	Net Access Unfav
Benefit	70.5	2.9	83.8	1.8	50.9	12.7	63.0	4.6
Useage	47.4	5.8	65.3	1.7	33.5	9.2	36.4	8.7
Effect	54.9	2.4	73.4	0.6	41.7	0.0	53.1	1.2

ment, that he would use this capability if it were available, or that it will make his job "easier." The numbers in this table represent the percentages of these responses to the total 173 returned questionnaires.

An unfavorable response, on the other hand, reflects a respondent's negative view toward a particular computer function. The respondent either expresses a perception that this function will not be beneficial to his clinic, that he sees no need for it, or that it will make his job "harder." The overall percentages of these responses, however, are much lower than favorable ones.

Consequently, based on the results of SPSS tests and the number of favorable responses to different utility questions, two conclusions can be drawn from this analysis. First, the order of preference for the four computer functions, based on total number of favorable responses, is as follows:

1. Data Base Management System.
2. Electronic Mail.
3. Network Access Capability.
4. Medical Diagnostic System.

Secondly, although the sampling population's make-up is not a perfect cross-section of medical personnel at WPMC, variations in background factors (such as current job, computer training, computer expertise, ownership of home computer, or satisfaction level with current computer capabilities at WPMC) would not have made significant impact upon the overall responses to utility questions of the four computer network functions. These findings could serve as a basis for implementation decisions or for further research in this area.

V. Summary, Conclusions, and Recommendations

Summary

Overview. The objective of this research was to examine functions that are available on existing local area computer networks, and from those, identify which network functions management should consider for implementation on a proposed Wright-Patterson AFB Medical Center (WPMC) network.

Research Strategy. The authors used three methods to select appropriate functions for consideration: a literature review of existing network systems at other medical centers, unstructured interviews with WPMC managers, and a survey of WPMC personnel. The first two methods examined all functions that have been successfully implemented on any network in the medical arena. This provided us with a working list of four computer functions. A survey was used to determine detailed WPMC personnel interest in these four functions.

Data Analysis Results. Three primary conclusions developed from data analysis:

1. A number of major functions have been successfully implemented on local area networks (LAN's) at large civilian medical centers around the United States (see Table I).
2. Medical center personnel have definite preferences for which functions would be most useful. The preferences are, in order, a data

base management system, an electronic mail system, network access capability, and a medical diagnostic system.

3. There is a need for further education of medical center personnel in computer network capabilities as evidenced by the number of "don't know" responses.

Implications. Improvements have been made in sky-rocketing medical costs and questionable patient care in large medical centers through the implementation of local area networks. Budget considerations suggest that WPMC's proposed network implement only those functions that are reported as being most successful, convenient and responsive to user needs. Failure to adequately consider medical center personnel interest could result in an ineffective computer network. Incorporating functions based on interest will give WPMC the best opportunity to follow the baseline of successful LAN-initiated improvements demonstrated by other large medical centers.

Conclusions and Recommendations

LAN's in Operation at Medical Centers--Conclusions. The use of computers in hospitals around the country has mushroomed. A major reason for this is better programs and less expensive start-up costs. The end result is a number of major successes in terms of cost containment and patient care. Success has not, however, been automatic.

Various problems have been reported in the installation and use of network functions at large medical centers. A consensus of hospital information system directors is that the key to LAN success lies not in the computer's stated capabilities, but rather in the users' perception of the system's convenience and responsiveness to individual needs.

LAN's in Operation at Medical Centers--Recommendations. The authors feel studying "lessons learned" at other locations can be invaluable to local managers. Particular attention should be paid to the degree of user acceptance, amount of individual use, and the subsequent affects on work performance of network functions implemented in large medical centers.

WPMC Personnel's Perceptions--Conclusions. Based on the results of the survey, medical personnel at WPMC expressed their preferences for the four key network functions that research indicates could have the most immediate and effective impact on medical center costs and patient care. In terms of benefits to their respective clinic, anticipated usage of each function, and potential effect on the way they perform their job, personnel reported the following preferences, in order:

1. Data base management system (DBMS).
2. Electronic mail system.
3. Network access capability.
4. Medical diagnostic system.

WPMC Personnel's Perceptions--Recommendations. Our second recommendation is to incorporate features in the users perceived order of utility. In doing so, it is possible to directly address one of the most prevalent problems with computer network functions in the country today--that problem being the abandonment of costly functions due to lack of acceptance and skepticism over possible benefits (16:425, 38:280, 37:22). An additional factor to insure acceptance is to insist on comprehensive studies and thorough design considerations.

First, studies need to be initiated to specifically determine user needs in each clinic or department. Much more information is necessary than just whether the user feels the function will benefit his clinic. Such questions as "what information is needed," "to whom will information be sent," and "how often" must be established in detail if a function is to be effectively employed.

Second, thorough design and customization of the actual software must be accomplished to incorporate features found to be necessary in the study phase. Use of the systems approach for this process would be appropriate to help insure all desired features are considered and incorporated.

If users have an initial positive attitude, they will probably be more receptive and thorough in answering questions about a computer function. Also, positive users should not get discouraged by initial minor operational flaws. Most importantly, optimistic personnel will make more of a deter-

mined effort to learn all of each function's operating characteristics. These theorized results of a positive attitude are key to making effective use of the LAN.

Further Computer Education--Conclusions. A significant number of medical center personnel (7 to 26 percent) indicated for each of the four functions that they didn't know how beneficial one might be, how much an individual would use one, or how a function would affect their job. This indicates a definite lack of user knowledge exists in terms of computer capabilities within the hospital.

Further Computer Education--Recommendations. A program of user education should be initiated by the computer specialists within the medical center. This education program should incorporate several key features.

First, medical center personnel need to know more about what network functions are and how the functions work. For instance, examples could be prepared of how a DBMS operates. The examples could be further developed by showing how a typical use might be performed--e.g., updating a patient record.

Second, examples of cost savings, productivity improvements, and operational characteristics of network functions at other medical centers need to be provided. Hospital personnel, seeing how successful a function is elsewhere, would perhaps be more inclined to use the feature in their own clinic.

The education program is critical to insure any LAN

function has widespread use and acceptance. Only twenty-one percent of surveyed personnel indicated they had any training in computers. This percentage must be raised if computer network functions with WPMC are to be successful and completely utilized.

Appendix A: Medical Center Computer Functions Questionnaire

1. What major clinic (department) do you work in? _______________

2. What is your current job (or position)?

   a. Clerk, stenographer or secretary.
   b. Technician.
   c. Nurse.
   d. Physician.
   e. Manager / Administrator.
   f. Other. _______________.

3. What is your highest level of formal education?

   a. Some high school (no diploma).
   b. High school graduate (no college).
   c. Some college or technical school.
   d. College graduate (Bachelor's degree).
   e. Some graduate work (no degree).
   f. Completed graduate degree (Master's degree).
   g. Some work beyond Master's degree (no Doctorate).
   h. Doctoral degree.

4. Have you had any training in computer programming or applications?

   a. No computer training at all.
   b. No formal classroom computer training.
   c. Some classroom computer courses (3 or less).
   d. Several classroom computer courses (more than 3).

5. How would you describe your current computer expertise?

   a. Complete beginner.
   b. Novice (still much to learn).
   c. Intermediate user (fairly knowledgeable).
   d. Advanced user (very knowledgeable).

6. Do you currently own a home computer?

   a. Yes.
   b. No.

7. On the average, how many hours of hands-on use per day are you currently spending with your clinic / office computer?

   a. None.
   b. Less than 1 hour.
   c. At least 1 hour, but less than 2.
   d. At least 2 hours, but less than 3.
   e. At least 3 hours, but less than 4.
   f. 4 hours or more.

8. Are you satisfied with the current computer capabilities at the medical center?

   a. Don't know.
   b. Very dissatisfied.
   c. Somewhat dissatisfied.
   d. Neither satisfied or dissatisfied.
   e. Somewhat satisfied.
   f. Very satisfied.

ELECTRONIC MAIL -- Computer function that allows the user to transmit messages instantaneously from one office to another via computer terminals. Other modes of transmission are broadcast service (to all terminals), multicast service (to selected terminals instantaneously), or sequential routing (to selected terminals sequentially).

9. In terms of improved message routing efficiency, do you feel your clinic / office will benefit from the electronic mail capability?

   a. Don't know.
   b. Definitely not beneficial.
   c. Not very beneficial.
   d. No difference.
   e. Somewhat beneficial.
   f. Definitely beneficial.
   g. Not applicable.

10. If the electronic mail function were available, would you use it?

   a. Don't know.
   b. No, I personally see no need for it.
   c. Yes, but not very often.
   d. Yes, as often as I could.
   e. Not applicable.

11. How do you anticipate the electronic mail function could affect the way you perform your job?

a. Don't know.
b. Make my job a lot harder.
c. Make my job a little harder.
d. Make no difference.
e. Make my job a little easier.
f. Make my job a lot easier.
g. Not applicable.

DATA BASE MANAGEMENT SYSTEM -- A computer function that allows the user to access an all-inclusive patient information storage area from any terminal within the medical center computer network. The user can then display or update instantaneously any part of a patients information file.

12. In terms of improved accessibility and currency of a patient's record, do you feel your clinic / office will benefit from the data base management system capability?

a. Don't know.
b. Definitely not beneficial.
c. Not very beneficial.
d. No difference.
e. Somewhat beneficial.
f. Definitely beneficial.
g. Not applicable.

13. If the data base management system capability were available, would you use it?

a. Don't know.
b. No, I personally see no need for it.
c. Yes, but not very often.
d. Yes, as often as I could.
e. Not applicable.

14. How do you anticipate the data base management system capability could affect the way you perform your job?

a. Don't know.
b. Make my job a lot harder.
c. Make my job a little harder.
d. Make no difference.
e. Make my job a little easier.
f. Make my job a lot easier.
g. Not applicable.

MEDICAL DIAGNOSTIC SYSTEM -- Computer function that can aid the user in diagnosing a patient's medical problem. Using the patient's medical history and reported symptoms as inputs, the computer will suggest possible ailment and treatment or medication based on statistical probabilities.

15. In terms of improved speed and accuracy of diagnoses, do you feel your clinic / office will benefit from the medical diagnostic system capability?

    a. Don't know.
    b. Definitely not beneficial.
    c. Not very beneficial.
    d. No difference.
    e. Somewhat beneficial.
    f. Definitely beneficial.
    g. Not applicable.

16. If the medical diagnostic system function were available, would you use it?

    a. Don't know.
    b. No, I personally see no need for it.
    c. Yes, but not very often.
    d. Yes, as often as I could.
    e. Not applicable.

17. How do you anticipate the medical diagnostic system function could affect the way you perform your job?

    a. Don't know.
    b. Make my job a lot harder.
    c. Make my job a little harder.
    d. Make no difference.
    e. Make my job a little easier.
    f. Make my job a lot easier.
    g. Not applicable.

NETWORK ACCESS CAPABILITY -- Computer function that allows the user to access networks of different medical center or university computers. In effect, this function makes available some information and processing services provided at other locations, thus serving as backup when the local system is malfunctioning.

18. In terms of improved information accessibility, do you feel your clinic / office will benefit from the network access capability?

    a. Don't know.
    b. Definitely not beneficial.
    c. Not very beneficial.
    d. No difference.
    e. Somewhat beneficial.
    f. Definitely beneficial.
    g. Not applicable.

19. If the network access function were available, would you use it?

    a. Don't know.
    b. No, I personally see no need for it.
    c. Yes, but not very often.
    d. Yes, as often as I could.
    e. Not applicable.

20. How do you anticipate the network access function could affect the way you perform your job?

    a. Don't know.
    b. Make my job a lot harder.
    c. Make my job a little harder.
    d. Make no difference.
    e. Make my job a little easier.
    f. Make my job a lot easier.
    g. Not applicable.

Appendix B: SPSS Frequencies Run

```
RUN NAME        FREQUENCY ANALYSIS
PRINT BACK      CONTROL
VARIABLE LIST   Q1 TO Q20
INPUT MEDIUM    CARD
N OF CASES      UNKNOWN
INPUT FORMAT    FIXED(20A1)
RECODE          Q1 TO Q20('A'=1)('B'=2)('C'=3)('D'=4)('E'=5)
                ('F'=6)('G'=7)('H'=8)('I'=9)(ELSE=0)
MISSING VALUES  Q1 TO Q20(0)
VAR LABELS      Q1,CLINIC/Q2,CURRENT JOB/Q3,EDUCATION LEVEL/Q4,
                COMPUTER TRAINING/Q5,COMPUTER EXPERTISE/Q6,
                OWN A COMPUTER/Q7,CURRENT COMPUTER USE/Q8,
                SATISFIED WITH COMPUTER CAPABILITY/Q9,BENEFIT
                FROM ELECTRONIC MAIL/Q10,USE ELECTRONIC MAIL/
                Q11,ELEC MAIL AFFECT JOB/Q12,BENEFIT FROM DBMS/
                Q13,USE DBMS/Q14,DBMS AFFECT JOB/Q15,BENEFIT
                FROM DIAGNOSTIC SYSTEM/Q16,USE DIAGNOSTIC
                SYSTEM/Q17,DIAGNOSTIC AFFECT JOB/Q18,BENEFIT
                FROM NETWORK/Q19,USE NETWORK ACCESS/Q20,NETWORK
                AFFECT JOB/
FREQUENCIES     GENERAL=Q1 TO Q20
STATISTICS      ALL
OPTIONS         3,8
*SELECT IF      (Q1 EQ 1)
FREQUENCIES     GENERAL=Q1 TO Q20
STATISTICS      ALL
OPTIONS         3,8
*SELECT IF      (Q1 EQ 2)
FREQUENCIES     GENERAL=Q1 TO Q20
STATISTICS      ALL
OPTIONS         3,8
*SELECT IF      (Q1 EQ 3)
FREQUENCIES     GENERAL=Q1 TO Q20
STATISTICS      ALL
OPTIONS         3,8
*SELECT IF      (Q1 EQ 4)
FREQUENCIES     GENERAL=Q1 TO Q20
STATISTICS      ALL
OPTIONS         3,8
*SELECT IF      (Q1 EQ 5)
FREQUENCIES     GENERAL=Q1 TO Q20
STATISTICS      ALL
OPTIONS         3,8
*SELECT IF      (Q1 EQ 6)
FREQUENCIES     GENERAL=Q1 TO Q20
STATISTICS      ALL
OPTIONS         3,8
*SELECT IF      (Q1 EQ 7)
```

```
FREQUENCIES     GENERAL=Q1 TO Q20
STATISTICS      ALL
OPTIONS         3,8
*SELECT IF      (Q1 EQ 8)
FREQUENCIES     GENERAL=Q1 TO Q20
STATISTICS      ALL
OPTIONS         3,8
*SELECT IF      (Q1 EQ 9)
FREQUENCIES     GENERAL=Q1 TO Q20
STATISTICS      ALL
OPTIONS         3,8
*SELECT IF      (Q1 EQ 10)
FREQUENCIES     GENERAL=Q1 TO Q20
STATISTICS      ALL
OPTIONS         3,8
*SELECT IF      (Q2 EQ 5)
FREQUENCIES     GENERAL=Q1 TO Q20
STATISTICS      ALL
OPTIONS         3,8
*RECODE         Q2(1,2,3,6=1)(4,5=2)(ELSE=0)
FREQUENCIES     GENERAL=Q1 TO Q20
STATISTICS      ALL
OPTIONS         3,8
READ INPUT DATA
```

Appendix C: Statistics Results

Background Questions

Q-2 Current Job	
1. Clerk	4.6
2. Tech	22.5
3. Nurse	26.0
4. Dr	21.4
5. Mgr	16.2
6. Other	9.2

Q-3 Education Level	
1. Some high sch	1.7
2. High school	5.2
3. Some college	31.8
4. College grad	23.7
5. Some grad wk	5.8
6. Grad Degree	7.5
7. Some beyond Grad	2.9
8. Doctorate	20.2

Q-4 Comput Train.	
1. None	50.9
2. No formal	27.2
3. Some clas	18.5
4. Sev class	2.9

Q6 Own a Computer	
1. Yes	19.1
2. No	80.9

Q-5 Expertise	
1. Begin.	50.3
2. Novice	37.0
3. Intmed	11.0
4. Adv	1.2

Q-7 Comput Use(hours)	
1. None	50.9
2. Less than 1 hour	30.6
3. 1 but < 2	6.4
4. 2 but < 3	1.2
5. 3 but < 4	2.3
6. 4 or more	6.9

Q8 Satisfaction	
1. Don't know	36.4
2. Very dissat	9.8
3. Some dissat	19.7
4. Neither	8.1
5. Some sat	18.5
6. Very sat	6.4

Utility Questions

Q9 Benefit Elec Mail	
1. Don't know	22.0
2. Def not	1.2
3. Not very	1.7
4. No difference	3.5
5. Somewhat	23.7
6. Definitely	46.8

Q10 Use Elec Mail	
1. Don't know	19.7
2. No	5.8
3. Occassion	25.4
4. Often	47.4

Q11 Mail Affect Job	
1. Don't know	25.4
2. Lot harder	1.2
3. Little hard	1.2
4. No diff	16.2
5. Little easy	32.9
6. Lot easier	22.0

Q12 Benefit DBMS	
1. Don't know	7.5
2. Def not	0.6
3. Not very	1.2
4. No difference	1.7
5. Somewhat	17.3
6. Definitely	66.5

Q13 Use DBMS	
1. Don't know	11.0
2. No	1.7
3. Occasion	15.0
4. Often	65.3

Q14 DBMS Affect Job	
1. Don't know	13.4
2. Lot harder	0.0
3. Little hard	0.6
4. No diff	8.1
5. Little easy	30.6
6. Lot easier	42.8

Q15 Benefit Med Diag	
1. Don't know	13.9
2. Def not	5.8
3. Not very	6.9
4. No difference	5.8
5. Somewhat	24.9
6. Definitely	26.0

Q16 Use Med Diag	
1. Don't know	17.3
2. No	9.2
3. Occasion	18.5
4. Often	33.5

Q17 Med Diag Affect	
1. Don't know	16.8
2. Lot harder	0.0
3. Little hard	0.0
4. No diff	20.2
5. Little easy	22.2
6. Lot easier	19.7

Q-18 Benefit Network	
1. Don't know	17.9
2. Def not	1.7
3. Not very	2.9
4. No difference	6.4
5. Somewhat	27.7
6. Definitely	35.3

Q-19 Use Network	
1. Don't know	20.8
2. No	8.7
3. Occasion	21.4
4. Often	36.4

Q-20 Net. Affect Job	
1. Don't know	22.5
2. Lot harder	0.6
3. Little hard	0.6
4. No diff	11.6
5. Little easy	30.6
6. Lot easier	22.5

Appendix D: SPSS T-TEST Program

```
RUN NAME        T-TEST OF FIVE GROUPS
PRINT BACK      CONTROL
VARIABLE LIST   Q1 TO Q20
INPUT MEDIUM    CARD
N OF CASES      UNKNOWN
INPUT MEDIUM    FIXED(20A1)
RECODE          Q1,Q3,Q6,Q7,Q10,Q13,Q16,Q19('A'=1)('B'=2)('C'=3)
                ('D'=4)('E'=5)('F'=6)('G'=7)('H'=8)('I'=9)
                (ELSE=0)/
                Q2('A'=1)('B'=1)('C'=1)('D'=2)('E'=2)('F'=1)(ELSE=0)/
                Q4 TO Q5('A'=1)('B'=1)('C'=2)('D'=2)(ELSE=0)/
                Q8('A'=0)('B'=1)('C'=2)('D'=0)('E'=2)('F'=2)(ELSE=0)/
                Q9,Q11,Q12,Q14,Q15,Q17,Q18,Q20('A'=0)('B'=1)('C'=2)
                ('D'=3)('E'=4)('F'=5)(ELSE=0)
MISSING VALUES  Q1 TO Q20(0)
VAR LABELS      Q1,CLINIC/Q2,CURRENT JOB/Q3,EDUCATION LEVEL/Q4,
                COMPUTER TRAINING/Q5,COMPUTER EXPERTISE/Q6,
                OWN A COMPUTER/Q7,CURRENT COMPUTER USE/Q8,
                SATISFIED WITH COMPUTER CAPABILITY/Q9,BENEFIT
                FROM ELECTRONIC MAIL/Q10,USE ELECTRONIC MAIL/
                Q11,ELEC MAIL AFFECT JOB/Q12,BENEFIT FROM DBMS/
                Q13,USE DBMS/Q14,DBMS AFFECT JOB/Q15,BENEFIT
                FROM DIAGNOSTIC SYSTEM/Q16,USE DIAGNOSTIC
                SYSTEM/Q17,DIAGNOSTIC AFFECT JOB/Q18,BENEFIT
                FROM NETWORK/Q19,USE NETWORK ACCESS/Q20,NETWORK
                AFFECT JOB/
T-TEST          GROUPS=Q2/VARIABLES=Q9 TO Q20
T-TEST          GROUPS=Q4/VARIABLES=Q9 TO Q20
T-TEST          GROUPS=Q5/VARIABLES=Q9 TO Q20
T-TEST          GROUPS=Q6/VARIABLES=Q9 TO Q20
T-TEST          GROUPS=Q8/VARIABLES=Q9 TO Q20
READ INPUT DATA
```

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The complex and heterogenous nature of hospital operations often posed a coordination and integration problem to computer system managers. This problem was further aggravated by the continued rising cost of operating and maintaining the information systems. Recent advancements in technology, however, helped to address these problems through the networking of computers. The use of a local area network (LAN) to link these systems opened up the potential for cost-effective distribution and coordinated sharing of information. This integration of different computers would also provide the users with additional computer functions previously unavailable. To help management at Wright-Patterson AFB Medical Center (WPMC) select the appropriate functions, this thesis focused on the medical personnel's perception of the usefulness of four network functions that had been successfully implemented at other medical centers. The order of preference for these functions, based on statistically analyzed data from eight departments at WPMC, are as follow: data base management system, electronic mail, network access capability, and medical diagnostic system. The administered questionnaire and method of analysis are presented, along with the results and their implications.

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